Hydrogen Safety

U.S. Department of Energy
Distributed Energy Road Show

Barriers and Status

Barriers

- Historical data is limited
- Rationale for current practice cannot be verified.
- Local government, Fire Marshal and public perceptions are shaped by past history.
- Creation and adoption of new codes and standards is a slow process.

Status

- Flammability studies indicate lean limit ≥ 6%
- Tests simulating a pressure relief device failure in a closed garage passed the residential fire code.
- Flame radiation values are extremely low.
- Bullet penetration tests were benign.

Hydrogen Fundamentals

- **Energy Content: 60,958 Btu/lb – highest energy content of all fuels on a weight basis**
  - This is why NASA uses hydrogen – they care a lot more about weight than volume)
  - Energy content is about three times higher than gasoline, natural gas, and propane on a **weight** basis
  - Energy content is only about one third that of natural gas and about an eighth that of propane on a **volume** basis
- **Flammability limits* (in air): 4.1 v% - 74 v%**
- **Explosion limits (in air): 18.3 v% - 59 v%**

* Recent results indicate the lower value may be greater than 6%

Hydrogen Today

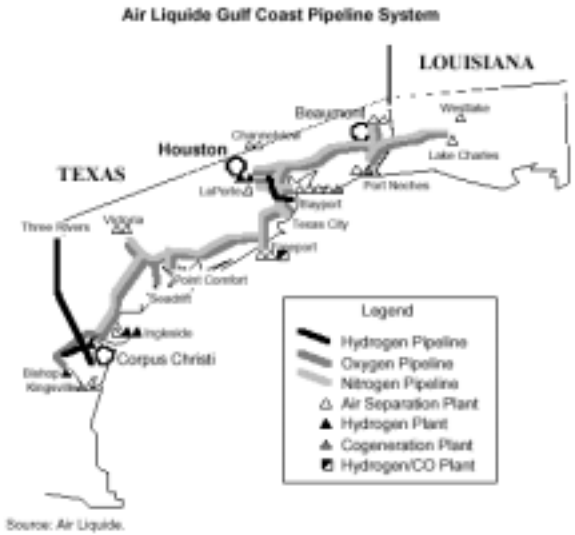
- **Production (9 million tons per year)**
  - Steam methane reforming
  - Electrolysis
  - Byproduct
- **Uses – largely in industrial settings**
  - Petroleum upgrading
  - Food processing (hydrogenation)
  - Semiconductor processing
  - NASA (only large-scale fuel use)
- **Transporting/Delivery**
  - Pipeline
  - Liquid tanker
  - Tube trailer (compressed gas)
  - Chemical carrier (ammonium)

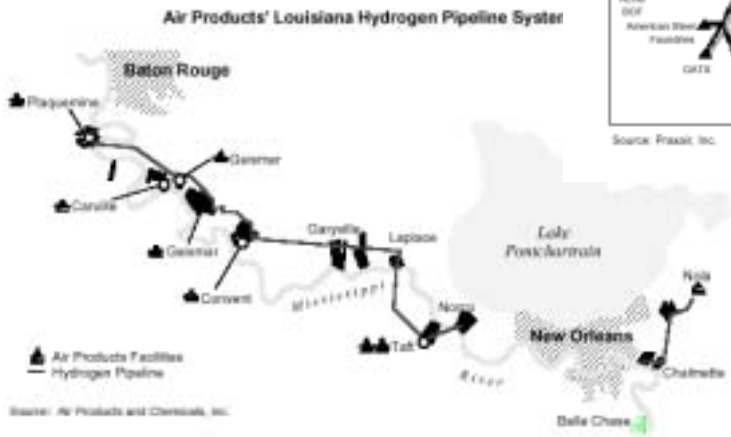
US Hydrogen Facilities

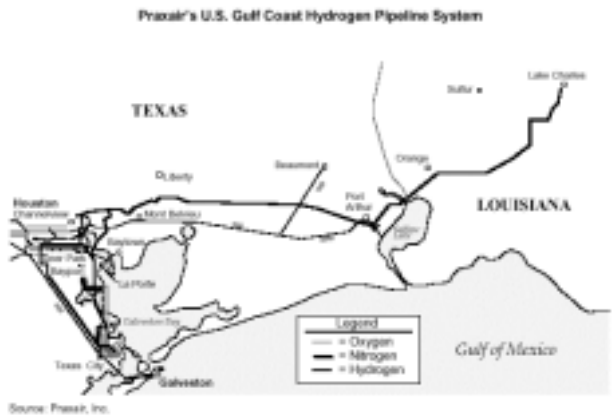
NASA Hydrogen Facilities

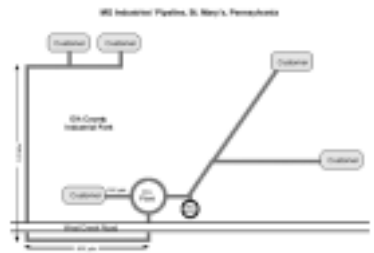
- **Single largest user of hydrogen for fuel**
- **Kennedy Space Center 850,000 gallon liquid storage**
- **Approximately 20 tank trucks driven in from Louisiana for each shuttle launch**

Hydrogen Pipelines









Codes and Standards

- Code-making bodies in the US
  - About 20 major developers (excluding federal agencies such as EPA and DOT)
  - Nearly all is done using a consensus process
- Must be adopted by each jurisdiction to be "legal" and binding
  - Approximately 44,000 jurisdictions in the US
  - Federal, state, county, city or town

Code Developers

- International Code Council, Inc. (ICC)
  - Building Officials and Code Administrators International (BOCA)
  - International Conference of Building Officials (ICBO)
  - Southern Building Code Congress International, Inc. (SBCC)
- Underwriters Laboratories (UL)
- National Fire Protection Association (NFPA)
- CSA International
- Society of Automotive Engineers (SAE)
- Institute of Electrical and Electronic Engineers (IEEE)
- American Society of Mechanical Engineers (ASME)
- International Electrotechnical Commission (IEC)
- International Organization for Standards (ISO)
- Compressed Gas Association (CGA)
- Natural Gas Institute (NGI)
- US Department of Transportation
- Occupational Health and Safety Administration (OHSA)

Issues

- **Codes & standards are being developed in advance of, or in parallel with, hydrogen-fueled systems**
  - Codes & standards development must be coordinated with technology development: follow a National Template
  - Efforts (funding) are being devoted to R&D to validate proposed standards (i.e., data to support or validate proposed requirements)
- **Coordination is vital**
  - All applications involve production, transportation, storage, dispensing, and use of hydrogen
  - A large number of organizations are involved in generating codes & standards

Technical Approach

1. 2004: Assemble panel of experts in hydrogen safety to provide expert technical guidance to funded projects.

2. 2006: With industry and code officials, develop templates of commercially viable footprints for fueling stations that incorporate underground and above ground storage of liquid and gaseous hydrogen.

3. 2008: Complete safety requirements and protocols for vehicle safety and stationary refueling.

4. 2010: Complete best management practices handbook for hydrogen safety.

Key Codes

Component Technology	Codes	Status
Production	NFPA 70/ NEC/CEC ASME Boiler-Pressure Vessel Sec. VIII	mature mature
Transportation:	DOT 49 CFR	mature mature
Pipeline	NEC/CEC ANSI/ASME B31.1, B31.8	mature mature
Storage	NFPA 50 A: Gaseous Hydrogen NFPA 50 B: Liquid Hydrogen ASME Boiler-Pressure Vessel Sec. VIII	mature (1994) mature (1994) mature
Vehicle Refueling Stations	HV-3: Hydrogen Vehicle Fuel NFPA 52: CNG Vehicle Fuel HV-1: Hydrogen Vehicle Connector NGV1: NGV connectors	being developed base for HV-3 being developed base for HV-1
Hydrogen Vehicles	HV-3: Hydrogen Vehicle Fuel NFPA 52: CNG Vehicle Fuel HV-2: Gaseous Hydrogen Tanks NGV2: CNG Storage Tanks	being developed base for HV-3 being developed base for HV-2

ISO-TC197

Identification Number	Title	Working Group	Convener (Country)
DIS 13984	Liquid H_2 - Land Vehicle Fueling System Interface	WG 1	SCC (Canada)
DIS 14687	H_2 Fuel-Product Specification	WG 3	ANSI (USA)
NP 15594	Airport H_2 Fueling Facility	WG 4	DIN (Germany)
NP 15866	Gaseous H_2 and H_2 Blends--Vehicular Fuel Systems	WG 5	ANSI (USA)
NP 15869	Gaseous H_2 - Vehicle fuel tanks	WG 6	ANSI (USA)
NP 15916	Basic requirements for safety of H_2 systems	WG 7	DIN (Germany)
WD 13985	Liquid H_2 - Land vehicle fuel tank		SCC (Canada)
WD 13986	Tank containers for multimodal transport of liquid H_2		SCC (Canada)

Fuel Systems Codes

Published/ Approved	In Progress	Requested/ Proposed
•CGA G-5 Hydrogen Commercial H2 •CGA G-5.3 Hydrogen Commercial Specification •CGA G-5.4 Hydrogen Piping Systems •CGA P-6 Hydrogen Standard Density Data •ICC Family Codes, Fire, Fuel, Mechanical, Electrical •ASME Boiler & Pressure Vessels •SAE J2600 Fueling Connectors	•UL 2264: Gaseous H2 generation •NFPA Codes: Fuel, Electrical, Storage •SAE J2601: Vehicle Communication	•ANSI/CSA NGV2[1] Fuel Containers •ISO TC197 WG5: H2 & H2 Blends Refueling •ANSI/CSA NGV 4[2] Dispensing Systems •SAE J1616 Recommended Practice •ISO TC-197 WG2 Tank Containers

Fuel Cell Codes

Published/ Approved	In Progress	Requested/ Proposed
•CSA CAS No. 33: Component Acceptance Service •CGA G-5.4 H2 Piping at Consumers •ICC Family Codes: Fire, Fuel, Mechanical Electrical •CSA Requirements 1.01 FC supplimental •ASME PTC 50 Performance Test •IEEE P1547 Interconnect Standard	•IEC TC 105 WG1 Terminology •UL 2265 Replacement FC Units •IEC TC105 WG2 FC Modules •IEC TC 105 WG3 FC Safety •NFPA 853 FC Installation •ANSI Z21.83/CSA FC-1 Fuel Cell Power Plants •NFPA Codes Fuel, Electrical, Storage •IEC TC 105 WG5 FC Installation •ISO TC 197 WG2 Containers and Hydrides •UL 1741 Inverters & Converters	•CSA FC-4 Fuel Cell Modules •ISO TC 58 Tanks & Enbrittlement

Hydrogen Delivery Codes

Published/ Approved	In Progress	Requested/ Proposed
•ASME B31.8 Gas Transmission & Distribution •CSA CAS No. 33 Component Acceptance Service •Part 1910 29 CFR OSH Standards •DOT Guide First Responders on Emergencies •ASME B31.4 Pipeline Transportation •CGA G-5.4 H2 Piping at Consumers •DOT 49 CFR Transportation of Hazardous Materials •ASME Boiler & Pressure Code •NFPA 58 Transport of LPG •NFPA 50A Gaseous H2 Systems •NFPA 50B Liquid H2 Systems	•ISO TC 197 WG2 Containers and Hydrides •NFPA 55 Combined 50 A&B	ISO TC 58 Tanks & Embrittlement

Hydrogen Automotive Codes

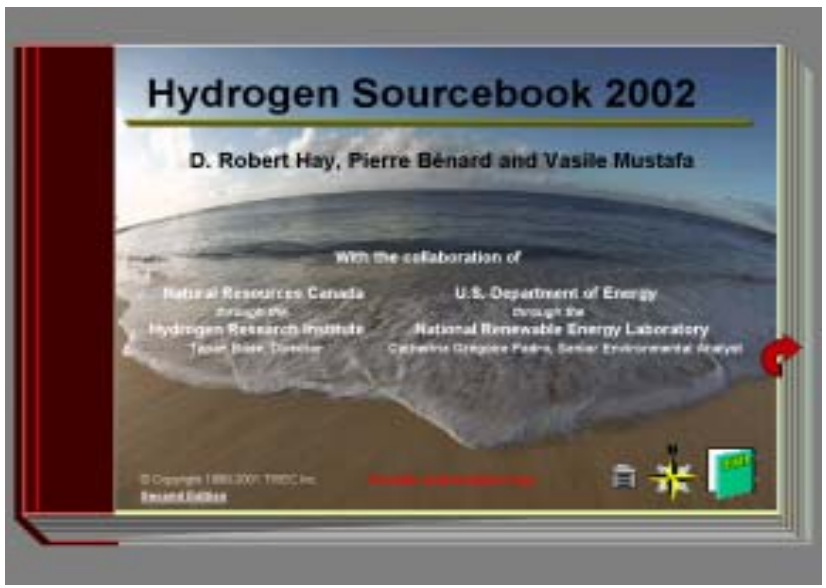
Published/ Approved	In Progress	Requested/ Proposed
•SAE J2574 Fuel Cell Vehicle Terminology •DOT/NHTSA Vehicle Regulations •SAE J2578 Recommended Practices for Vehicle Safety •SAE J2579 Recommended Practices for Hazardous Fluid Systems	•SAE J2594 Fuel Cell Recyclability Guidelines •SAE J2615 Performance Test Procedures for Fuel Cell Systems •SAE J2616 Performance for Fuel Processor Subsystem •SAE J2617 Performance Test Procedures of PEM FC Stack Subsystem •SAE J2600 Compressed Hydrogen Fueling Connectors •SAE J2572 Recommended Practice Exhaust Emissions •SAE J2601 Compressed Hydrogen Fueling Communication	•ISO TC 197 Compressed Hydrogen Fueling Connectors • CSA/NGV2 Fuel Tanks for Hydrogen

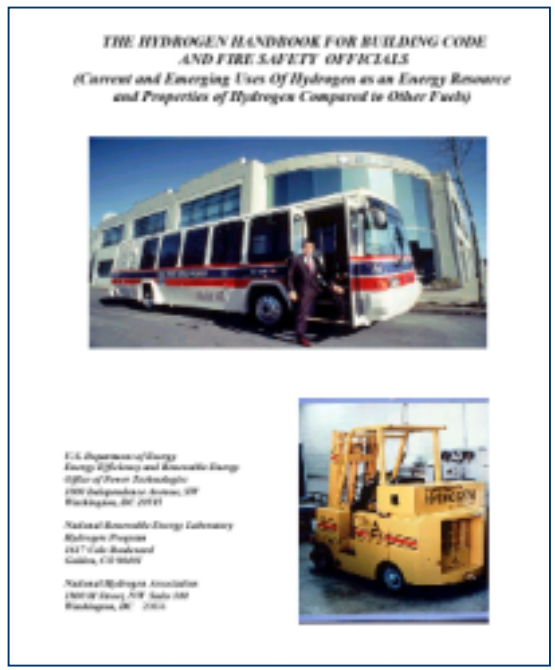
Hydrogen Uses – Tomorrow

- Mobile Applications
  - Fuel cell vehicles (buses, trucks, passenger)
  - Marine vehicles (submarines, ships, pleasure craft)
  - Modified ICEs
- Stationary Applications
  - Uninterruptible power supplies
  - Backup/premium power
  - CHP
- Portable Applications

Guidelines for Hydrogen Systems

- The Hydrogen Handbook for Building Code and Fire Safety Officials
- The Hydrogen Sourcebook
- Permitting Stationary Fuel Cells
- Permitting Hydrogen Fuel Stations



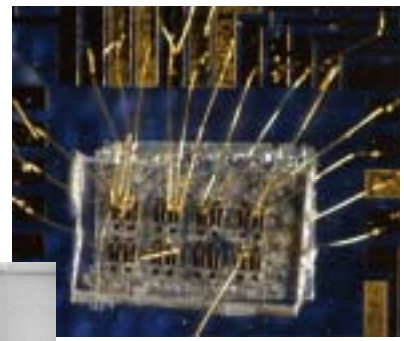


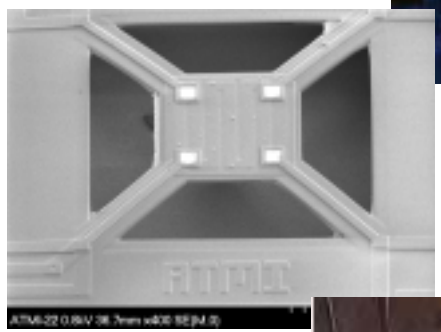
Typical Hydrogen Site Plan Review

- Confinement
- Review Potential for Ignition
- Minimizing Consequences
- Review the Need for Detectors
- Safety Analysis
- Review Site-Specific Factors
- Personal Investigation

Detection

- **Sensors**
  - Safe, reliable, cheap sensors under development
  - Hand held and personnel sensors are needed
  - Requirements dictated by application
- **Odorants/Tracers**
  - Diffusion/dispersion correlation may be a requirement
  - Cost, Uniqueness and Impact on fuel cells





Safe Hydrogen Systems

- Safety issues can be handled through testing, certification, and codes & standards, just like with any other fuel
- Sustained, collaborative government-industry RD&D is underway
  - Fuel cell and vehicle systems development are critical
  - Infrastructure and codes & standards development require significant government participation (on all levels)
  - Coordination is key

For more information:

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